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# (54) BATTERY SYSTEM AND CONTROL METHOD OF BATTERY SYSTEM

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***B60L 11/18*** (2006.01)
***H02H 9/00*** (2006.01)

(52) **U.S. Cl.**
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USPC ................................................. 320/120–127
See application file for complete search history.

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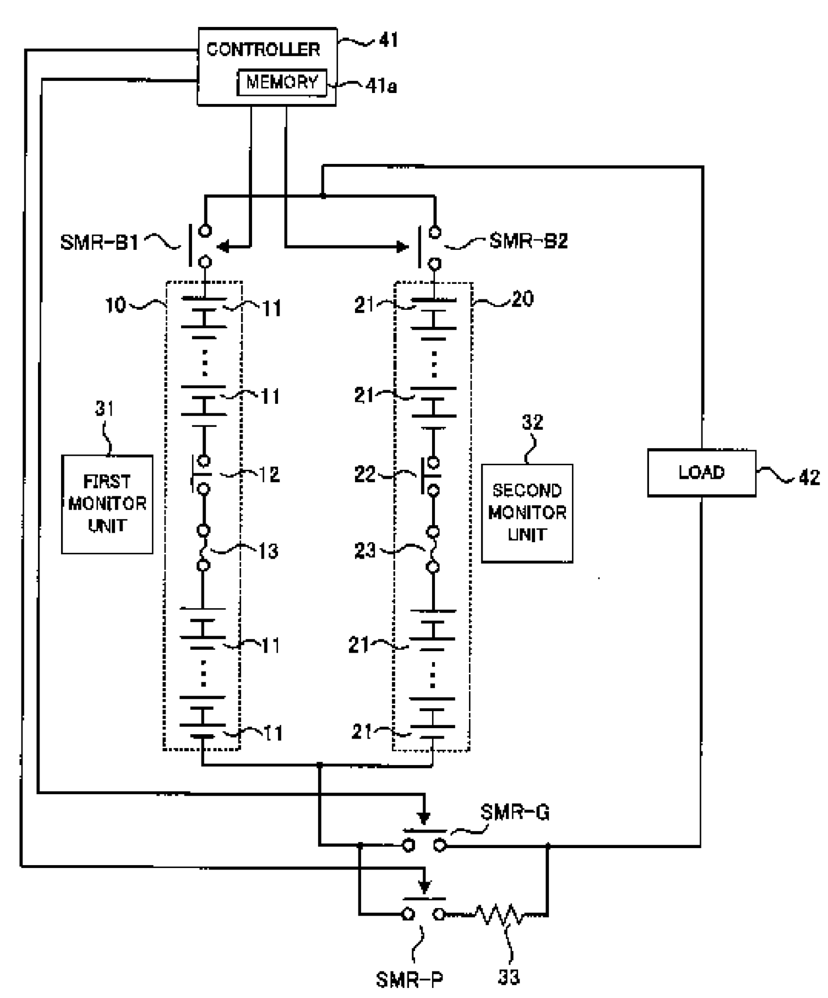
(57) **ABSTRACT**

A battery system includes a first battery and a second battery connected in parallel and performing charge and discharge. A first relay is switched between an ON state in which the charge and discharge of the first battery are allowed and an OFF state in which the charge and discharge of the first battery are prohibited. A second relay is switched between an ON state in which the charge and discharge of the second battery are allowed and an OFF state in which the charge and discharge of the second battery are prohibited. A controller controls the ON state and the OFF state of each of the first relay and the second relay. The controller also changes the order in which the first relay and the second relay are switched to the ON state, in performing the charge and discharge of the first battery and the second battery.

**18 Claims, 4 Drawing Sheets**



(52) **U.S. Cl.**
CPC ................ *Y02T 90/12* (2013.01); *Y02T 90/121* (2013.01); *Y02T 90/14* (2013.01)

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FIG. 1

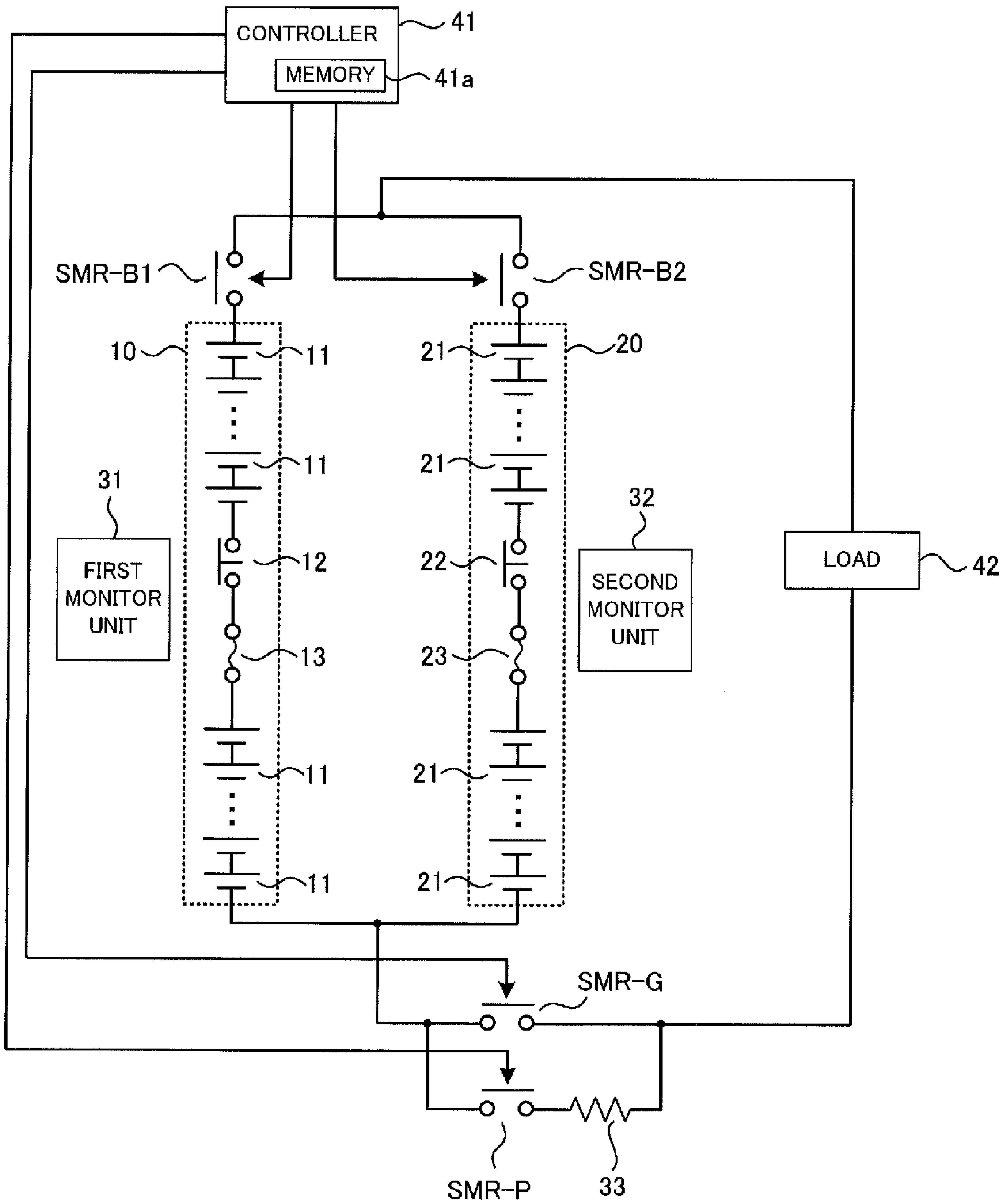

CONTROLLER
41
MEMORY
41a
SMR-B1
SMR-B2
10
11
21
20
11
21
31
32
FIRST MONITOR UNIT
12
22
SECOND MONITOR UNIT
LOAD
42
13
23
11
21
11
21
SMR-G
SMR-P
33

FIG. 2

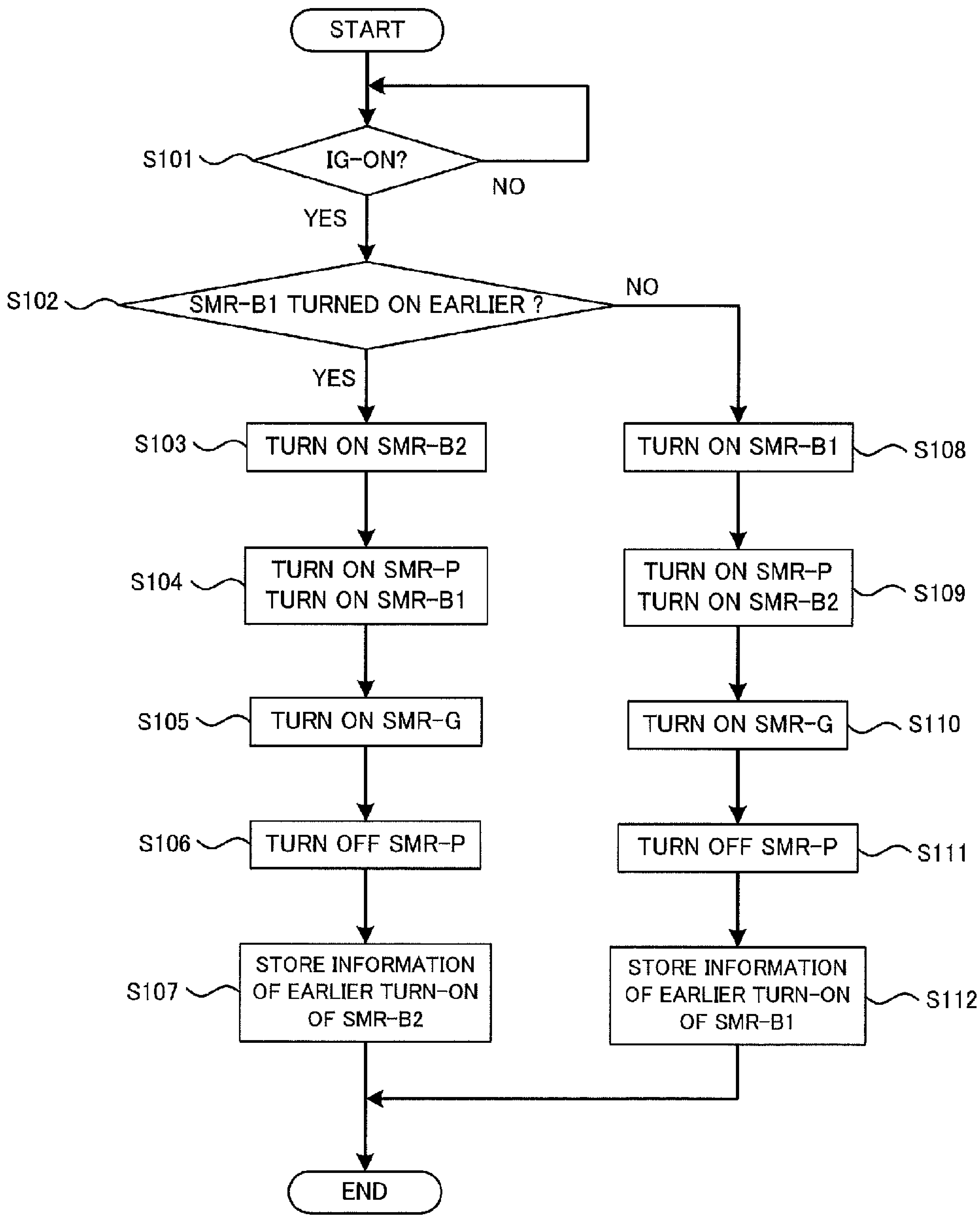

START
S101
IG-ON?
NO
YES
S102
SMR-B1 TURNED ON EARLIER ?
NO
YES
S103
TURN ON SMR-B2
TURN ON SMR-B1
S108
S104
TURN ON SMR-P
TURN ON SMR-B1
TURN ON SMR-P
TURN ON SMR-B2
S109
S105
TURN ON SMR-G
TURN ON SMR-G
S110
S106
TURN OFF SMR-P
TURN OFF SMR-P
S111
S107
STORE INFORMATION
OF EARLIER TURN-ON
OF SMR-B2
STORE INFORMATION
OF EARLIER TURN-ON
OF SMR-B1
S112
END

FIG. 3

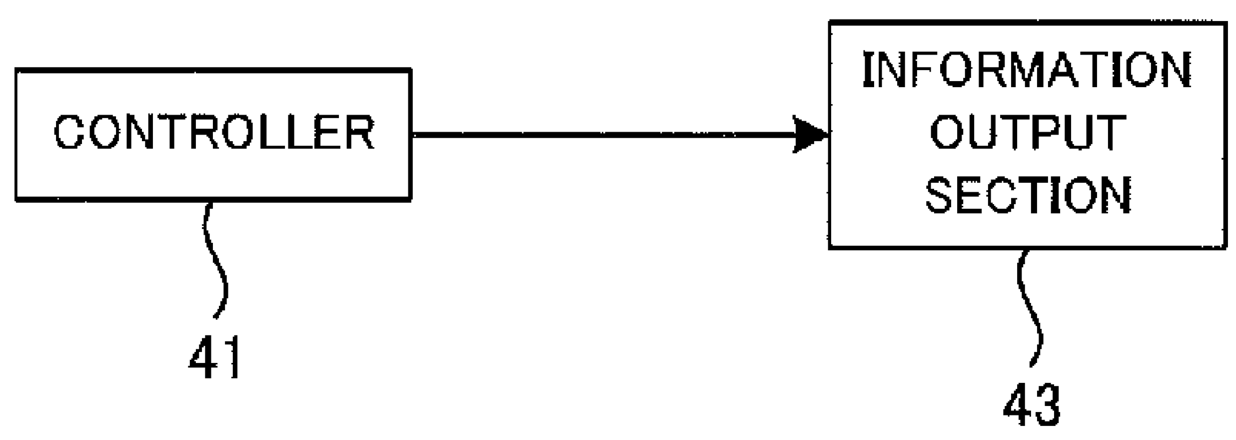

CONTROLLER
INFORMATION OUTPUT SECTION
41
43

FIG. 4

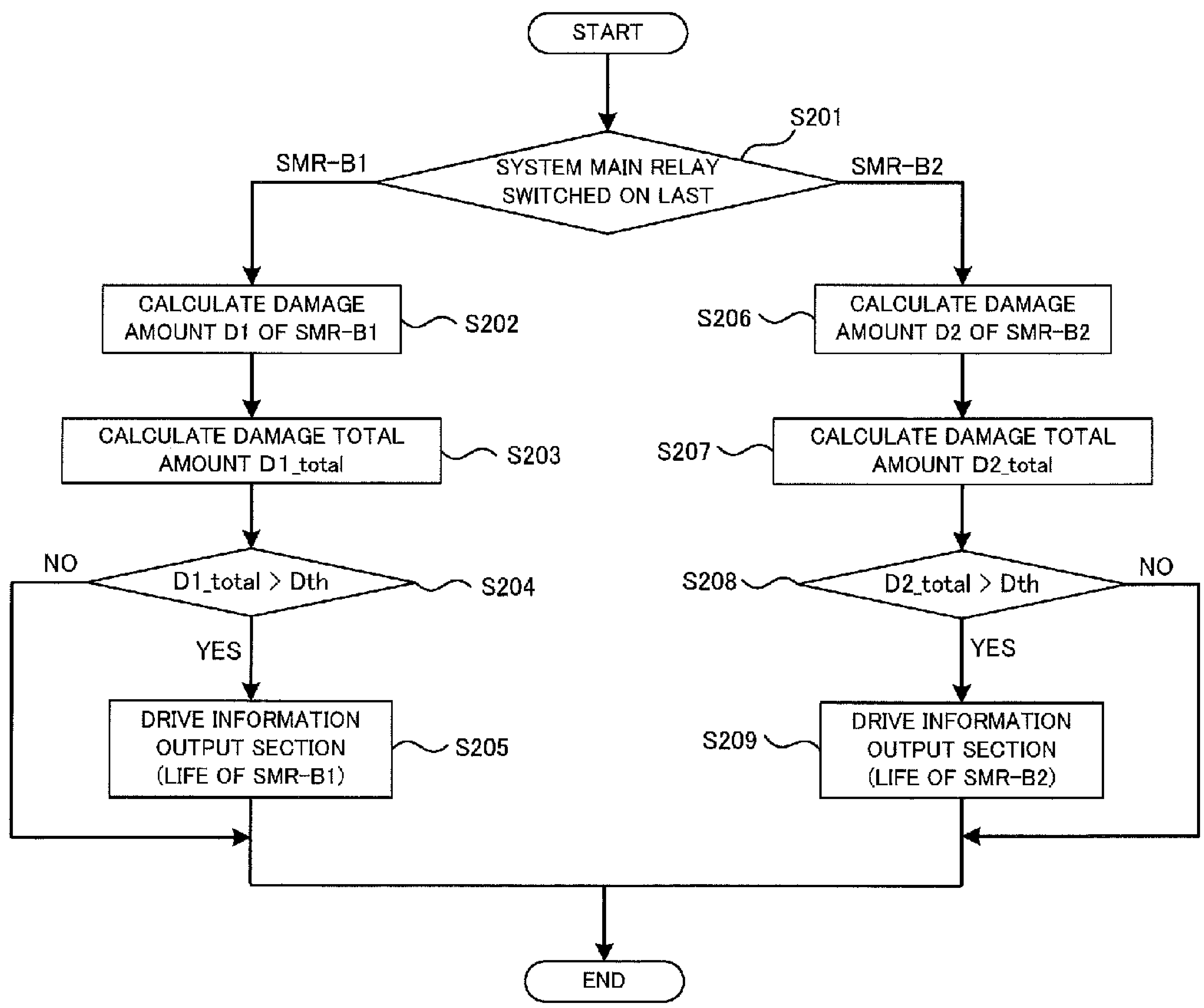
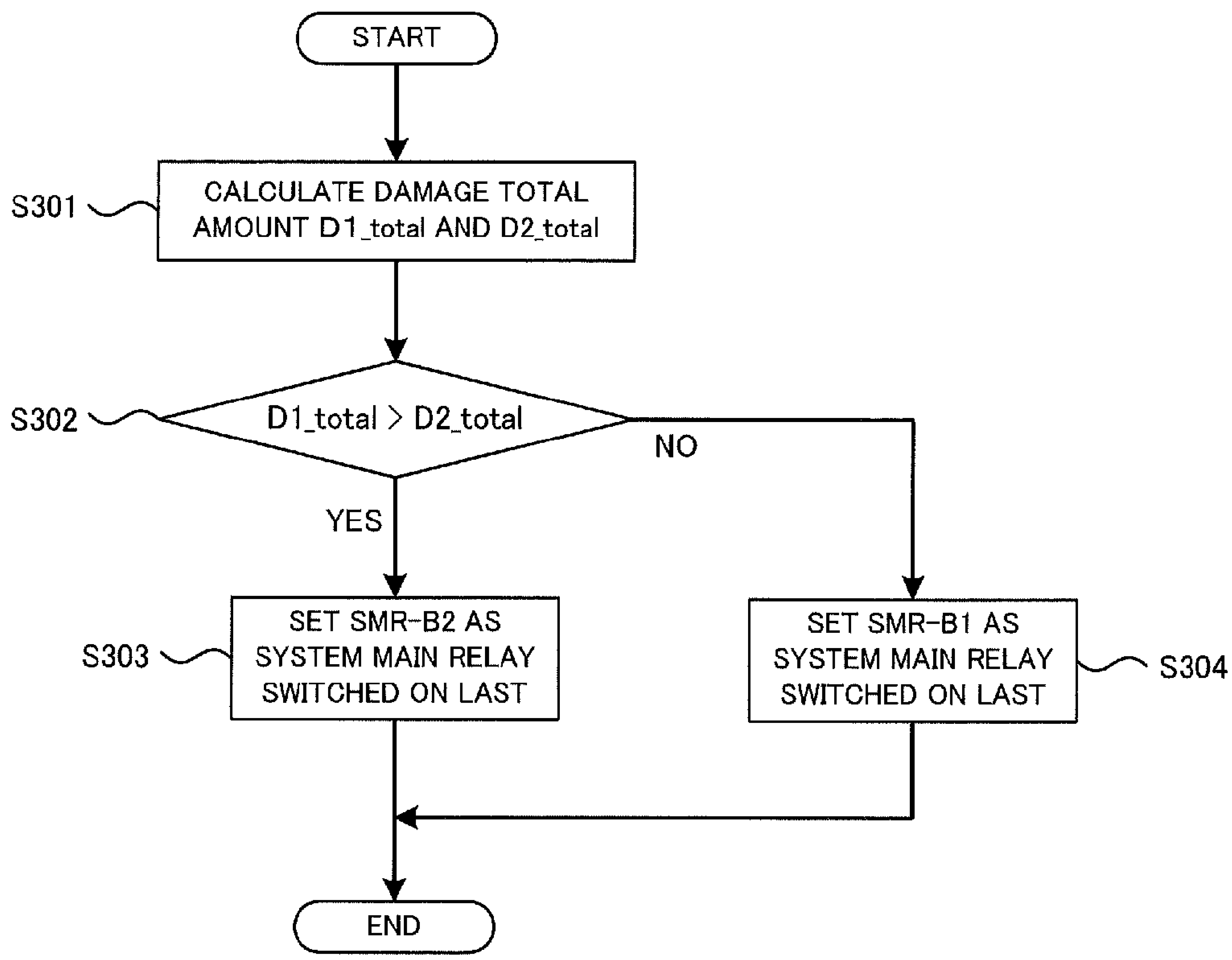

START
SYSTEM MAIN RELAY SWITCHED ON LAST
S201
SMR-B1
SMR-B2
CALCULATE DAMAGE AMOUNT D1 OF SMR-B1
S202
CALCULATE DAMAGE TOTAL AMOUNT D1_total
S203
D1_total > Dth
S204
NO
YES
DRIVE INFORMATION OUTPUT SECTION (LIFE OF SMR-B1)
S205
CALCULATE DAMAGE AMOUNT D2 OF SMR-B2
S206
CALCULATE DAMAGE TOTAL AMOUNT D2_total
S207
D2_total > Dth
S208
NO
YES
DRIVE INFORMATION OUTPUT SECTION (LIFE OF SMR-B2)
S209
END

FIG. 5


START
S301
CALCULATE DAMAGE TOTAL AMOUNT D1_total AND D2_total
S302
D1_total > D2_total
NO
YES
S303
SET SMR-B2 AS SYSTEM MAIN RELAY SWITCHED ON LAST
SET SMR-B1 AS SYSTEM MAIN RELAY SWITCHED ON LAST
S304
END

# BATTERY SYSTEM AND CONTROL METHOD OF BATTERY SYSTEM

This is a 371 national phase application of PCT/JP2011/003205 filed 7 Jun. 2011, the contents of which are incorporated herein by reference.

## FIELD OF THE INVENTION

The present invention relates to a battery system in which a first battery and a second battery are connected in parallel, and to a technology for controlling charge and discharge of the battery system.

## BACKGROUND OF THE INVENTION

In a battery system, an assembled battery is connected to a load. In some battery systems, a plurality of assembled batteries are connected in parallel and those assembled batteries are connected to a load. In a configuration in which the plurality of assembled batteries are connected in parallel, a relay is provided for each of the assembled batteries. The relay is used to allow or prohibit charge and discharge of each of the assembled batteries.

## PRIOR ART DOCUMENTS

### Patent Documents

[Patent Document 1] Japanese Patent Laid-Open No. 2009-291016

[Patent Document 2] Japanese Patent Laid-Open No. 2010-124536

## SUMMARY OF THE INVENTION

### Problems to be Solved by the Invention

When the plurality of assembled batteries are connected in parallel, an OCV (Open Circuit Voltage) may vary among the plurality of assembled batteries. If the relay associated with each of the assembled batteries is switched from OFF to ON in the state in which the OCV varies, an inrush current may flow from the assembled battery having a higher OCV to the assembled battery having a lower OCV.

When the relays associated with the assembled batteries are turned ON indifferent timings, an inrush current may flow to the relay which is turned ON last, and that relay may be subjected to a thermal load due to the inrush current. The relay suffers damage due to the thermal load.

### Means for Solving the Problems

A battery system according to the present invention has a first battery and a second battery connected in parallel and performing charge and discharge. A first relay is switched between an ON state in which the charge and discharge of the first battery are allowed and an OFF state in which the charge and discharge of the first battery are prohibited. A second relay is switched between an ON state in which the charge and discharge of the second battery are allowed and an OFF state in which the charge and discharge of the second battery are prohibited. A controller controls the ON state and the OFF state of each of the first relay and the second relay. The controller also changes the order in which the first relay and



the second relay are switched to the ON state, in performing the charge and discharge of the first battery and the second battery.

The order in which the first relay and the second relay are switched to the ON state can be changed each time the charge and discharge of the first battery and the second battery are performed.

Damage due to a thermal load when each of the first relay and the second relay is switched from the OFF state to the ON state can be estimated on the basis of a terminal voltage of each of the first relay in the OFF state and the second relay in the OFF state. One of the first relay and the second relay that has smaller estimated damage can be switched last to the ON state, in performing the charge and discharge of the first battery and the second battery.

Since the relay switched last to the ON state may suffer damage, the relay having the smaller estimated damage can be switched last to the ON state to prevent the particular relay from being more damaged.

An information output section can be provided which outputs information about the life of each of the first relay and the second relay. The damage to each of the first relay and the second relay is estimated as described, and when the estimated damage reaches a threshold value, the information output section can be driven. This can notify a user or the like of the relay with the damage reaching the threshold value, in other words, the relay with the life expiring, through the information output section.

A third relay can be provided which is switched between an ON state in which the charge and discharge of the first battery and the second battery are allowed and an OFF state in which the charge and discharge of the first battery and the second battery are prohibited. For example, the first relay and the second relay can be connected to positive electrode terminals of the first battery and the second battery, respectively, and the third relay can be connected to negative electrode terminals of the first battery and the second battery.

Each of the first battery and the second battery can be provided by using an assembled battery formed of a plurality of cells connected in series. Outputs of the first battery and the second battery can be used for running of a vehicle.

According to a second aspect of the present application, a control method of a battery system is provided. The battery system includes a first battery and a second battery connected in parallel and performing charge and discharge, a first relay, and a second relay. The first relay is switched between an ON state in which the charge and discharge of the first battery are allowed and an OFF state in which the charge and discharge of the first battery are prohibited. The second relay is switched between an ON state in which the charge and discharge of the second battery are allowed and an OFF state in which the charge and discharge of the second battery are prohibited. The order in which the first relay and the second relay are switched to the ON state is changed in performing the charge and discharge of the first battery and the second battery.

### Advantage of the Invention

According to the present invention, the order in which the first relay and the second relay are switched to the ON state is changed. In other words, the relay switched last to the ON state is switched between the first relay and the second relay. This can share the thermal load due to inrush current between the first relay and the second relay to suppress the deterioration of the first relay and the second relay.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram showing the configuration of a battery system which is Embodiment 1.

FIG. **2** is a flow chart for describing the operation of the battery system which is Embodiment 1.

FIG. **3** is a diagram showing the configuration of part of a battery system which is Embodiment 2.

FIG. **4** is a flow chart for describing the operation of the battery system which is Embodiment 2.

FIG. **5** is a flow chart for describing the operation of a battery system which is Embodiment 3.

## DETAILED DESCRIPTION

Embodiments of the present invention will hereinafter be described.

### Embodiment 1

A battery system which is Embodiment 1 of the present invention is described with reference to FIG. **1**. FIG. **1** is a diagram showing the configuration of the battery system.

A first battery pack (corresponding to a first battery) **10** and a second battery pack (corresponding to a second battery) **20** are connected in parallel. The first battery pack **10** has a plurality of cells **11** connected in series. The second battery pack **20** has a plurality of cells **21** connected in series.

A secondary battery such as a nickel metal hydride battery and a lithium-ion battery can be used as each of the cells **11** and **21**. Instead of the secondary battery, an electric double layer capacitor can be used. In the present embodiment, at least one of the first battery pack **10** and the second battery pack **20** may include a plurality of cells connected in parallel.

The number of the cells **11** constituting the first battery pack **10** and the number of the cells **21** constituting the second battery pack **20** can be set as appropriate in view of the required output and the like. The number of the cells **11** and the number of the cells **21** may be equal to or different from each other.

The same type (same characteristics) of cell can be used as the cells **11** and **21**. Alternatively, different types (different characteristics) of cell may be used as the cells **11** and **21**. For example, the cell **11** can be provided by using a cell capable of charge and discharge with a current larger than that in the cell **21**, and the cell **21** can be provided by using a cell having an electric storage capacitance larger than that of the cell **11**.

The first battery pack **10** and the second battery pack **20** have service plugs (current breaker) **12** and **22**, respectively. The service plugs **12** and **22** are used to break electric currents passing through the first battery pack **10** and the second battery pack **20**, respectively. Specifically, the service plugs **12** and **22** can be physically removed from the battery packs **10** and **20** to break current paths in the battery packs **10** and **20**, respectively. The battery packs **10** and **20** have fuses **13** and **23**, respectively.

A system main relay (corresponding to a first relay) SMR-B**1** is connected to a positive electrode terminal of the first battery pack **10**. A system main relay (corresponding to a second relay) SMR-B**2** is connected to a positive electrode terminal of the second battery pack **20**. The system main relays SMR-B**1** and SMR-B**2** are connected in parallel. Each of the system main relays SMR-B**1** and SMR-B**2** is switched between ON and OFF in response to a control signal from a controller **41**.

While the system main relay SMR-B**1** is ON, charge and discharge of the first battery pack **10** can be performed. While the system main relay SMR-B**1** is OFF, charge and discharge of the first battery pack **10** can be prohibited. While the system main relay SMR-B**2** is ON, charge and discharge of the second battery pack **20** can be performed. While the system main relay SMR-B**2** is OFF, charge and discharge of the second battery pack **20** can be prohibited.



A system main relay (corresponding to a third relay) SMR-G is connected to negative electrode terminals of the first battery pack **10** and the second battery pack **20**. The system main relay SMR-G is switched between ON and OFF in response to a control signal from the controller **41**. While the system main, relay SMR-G is ON, charge and discharge of the first battery pack **10** and the second battery pack **20** can be performed.

A system main relay SMR-P is connected in series with a limiting resistor **33**. The system main relay SMR-P and the limiting resistor **33** are connected in parallel with the system main relay SMR-G. The limiting resistor **33** is used to suppress a flow of inrush current.

The first battery pack **10** and the second battery pack **20** are connected to a load **42**. When the system main relays SMR-B**1** and SMR-G are ON, the first battery pack **10** can be connected to the load **42**. When the system main relays SMR-B**2** and SMR-G are ON, the second battery pack **20** can be connected to the load **42**.

The battery packs **10** and **20** can be mounted on a vehicle, for example. Specifically, the battery packs **10** and **20** can be used as a power source for running of the vehicle. When the battery packs **10** and **20** are mounted on the vehicle, a motor generator can be used as the load **42**.

The motor generator (load) **42** can receive an electric energy from each of the battery packs **10** and **20** to generate a kinetic energy for running of the vehicle. On the other hand, for decelerating or stopping the vehicle, the motor generator (load) **42** can convert a kinetic energy produced in breaking of the vehicle into an electric energy. The electric energy generated by the motor generator (load) **42** can be stored as regenerative power in the battery packs **10** and **20**.

A step-up circuit or an inverter may be placed between the motor generator and the battery packs **10** and **20**. The step-up circuit can increase an output voltage of each of the battery packs **10** and **20**. The step-up circuit can also reduce an output voltage of the motor generator. The inverter can convert a DC power from each of the battery packs **10** and **20** into an AC power. When the inverter is used, an AC motor can be used as the motor generator. The inverter can convert an AC power from the AC motor into a DC power.

A first monitor unit **31** monitors the state of the first battery pack **10**. The monitored state of the first battery pack **10** includes, for example, the voltage, the current, and the temperature of the first battery pack **10**. The first monitor unit **31** has the function of equalizing the voltages among the plurality of cells **11**.

Specifically, the first monitor unit **31** detects the voltage of each of the cells **11**. When the voltage varies among the plurality of cells **11**, the first monitor unit **31** can discharge only a particular one of the cells **11** to reduce the variations in voltage. A switching element and a resistor are connected in parallel with each of the cells **11**, and the first monitor unit **31** can turn on the switching element to discharge only the particular cell **11**.

A second monitor unit **32** monitors the state of the second battery pack **20**. The monitored state of the second battery pack **20** includes, for example, the voltage, the current, and the temperature of the second battery pack **20**. The second monitor unit **32** has the function of equalizing the voltages among the plurality of cells **21**. The second monitor unit **32** can have the same circuit configuration as that of the first monitor unit **31**.

Description is now made of operation in controlling charge and discharge of the first battery pack **10** and the second battery pack **20** with reference to a flow chart shown in FIG. **2**. Processing shown in FIG. **2** is performed in connecting the battery packs **10** and **20** to the load **42** in the vehicle on which the battery packs **10** and **20** are mounted. The processing shown in FIG. **2** is performed by the controller **41**.

At step S**101**, the controller **41** determines whether or not an ignition switch of the vehicle is switched from OFF to ON. When the ignition switch is switched from OFF to ON, the process proceeds to step S**102**.

At step S**102**, the controller **41** determines whether or not the system main relay SMR-B**1** was switched from OFF to ON earlier than the system main relay SMR-B**2** in the previous processing. The previous processing refers to the latest processing of the processing (the processing shown in FIG. **2**) performed at the switching of the ignition switch from OFF to ON.

When the system main relay SMR-B**1** was switched from OFF to ON earlier than the system main relay SMR-B**2** in the previous processing, the process proceeds to step S**103**, and when not, the process proceeds to step S**108**.

Information indicating which of the system main relays SMR-B**1** and SMR-B**2** was switched from OFF to ON earlier can be stored in a memory **41***a* (see FIG. **1**) contained in the controller **41**. While the memory **41***a* is contained in the controller **41** in the present embodiment, the memory **41***a* may be placed outside the controller **41**.

At step S**103**, the controller **41** switches the system main relay SMR-B**2** from OFF to ON. The system main relay SMR-B**1** remains OFF.

At step S**104**, the controller **41** switches the system main relays SMR-P and SMR-B**1** from OFF to ON. This causes the first battery pack **10** and the second battery pack **20** to be connected to the load **42**. Charge and discharge currents of the battery packs **10** and **20** pass through the limiting resistor **33**.

The controller **41** switches the system main relay SMR-G from OFF to ON at step S**105**, and switches the system main relay SMR-P from ON to OFF at step S**106**.

This completes the connection between the battery packs **10** and **20** and the load **42**. When the powers of the battery packs **10** and **20** are supplied to the load (motor generator) **42**, the vehicle can be run. In breaking of the vehicle, the battery packs **10** and **20** can store the power from the load (motor generator) **42**.

At step S**107**, the controller **41** stores information indicating that the system main relay SMR-B**2** was switched ON earlier than the system main relay SMR-B**1** in the memory **41***a*. The information stored in the memory **41***a* is updated each time the ignition switch is switched from OFF to ON. The information stored in the memory **41***a* is used in the processing at step S**102** when the ignition switch is switched from OFF to ON next.

On the other hand, at step S**108**, the controller **41** switches the system main relay SMR-B**1** from OFF to ON. The system main relay SMR-B**2** remains OFF.

At step S**109**, the controller **41** switches the system main relays SMR-P and SMR-B**2** from OFF to ON. This causes the first battery pack **10** and the second battery pack **20** to be connected to the load **42**. Charge and discharge currents of the battery packs **10** and **20** pass through the limiting resistor **33**.

The controller **41** switches the system main relay SMR-G from OFF to ON at step S**110**, and switches the system main relay SMR-P from ON to OFF at step S**111**. This completes the connection between the battery packs **10** and **20** and the load **42**.

At step S**112**, the controller **41** stores information indicating that the system main relay SMR-B**1** was switched ON earlier than the system main relay SMR-B**2** in the memory **41***a*. The information stored in the memory **41***a* is updated each time the ignition switch is switched from OFF to ON. The information stored in the memory **41***a* is used in the processing at step S**102** when the ignition switch is switched from OFF to ON next.

In the battery system of the present embodiment, a difference in OCV (Open Circuit Voltage) may occur between the first battery pack **10** and the second battery pack **20**. Possible causes of the different OCVs include the following.

A difference in resistance occurs between the first battery pack **10** and the second battery pack **20** due to different temperatures or different deterioration states thereof. On the other hand, since the first battery pack **10** and the second battery pack **20** are connected in parallel, CCVs (Closed Circuit Voltage) of the battery packs **10** and **20** are equal to each other. The CCV and the OCV have the relationship represented by the following expression (1).

$$CCV=OCV+IR \tag{1}$$

where I represents an electric current passing through each of the battery packs **10** and **20**, and R represents an internal resistance of each of the battery packs **10** and **20**.

When the difference in resistance occurs between the battery packs **10** and **20**, the OCVs of the battery packs **10** and **20** are different from each other even when the CCVs of the battery packs **10** and **20** are equal to each other.

On the other hand, the OCVs of the battery packs **10** and **20** may be different from each other in association with variations in self-discharge characteristics between the battery packs **10** and **20**. For example, when the battery packs **10** and **20** are left at rest for a long time, the OCVs of the battery packs **10** and **20** tend to be different from each other.

In the battery system of the present embodiment, the first monitor unit **31** and the second monitor unit **32** are provided for the first battery pack **10** and the second battery pack **20**, respectively. Thus, the monitor units **31** and **32** perform the equalization processing individually in the first battery pack **10** and the second battery pack **20**. The independent equalization processing may result in a difference in OCV between the battery packs **10** and **20**.

When the difference in OCV occurs between the first battery pack **10** and the second battery pack **20**, an inrush current may pass from the battery pack having the higher OCV into the battery pack having the lower OCV at the switching of the system main relays SMR-B**1** and SMR-B**2** from OFF to ON. The system main relays SMR-B**1** and SMR-B**2** are switched from OFF to ON in different timings. Thus, the system main relay switched last from OFF to ON is more deteriorated due to a thermal load due to the inrush current.

If the system main relays. SMR-B**1** and SMR-B**2** are always switched from OFF to ON in the same order, only one of the system main relays SMR-B**1** and SMR-B**2** is concentratedly subjected to the thermal load due to the inrush current. In this case, the life of the only one of the system main relays is shortened.

In the present embodiment, the switching order of the system main relays SMR-B**1** and SMR-B**2** from OFF to ON is changed as described with reference to FIG. **2**. Specifically, each time the ignition switch is switched ON, the system main relays SMR-B**1** and SMR-B**2** are alternately set as the system main relay switched last from OFF to ON.

This allows the thermal load due to the inrush current to be shared between both of the system main relays SMR-B**1** and SMR-B**2**. The sharing of the thermal load can prevent concentration of the thermal load on one of the system main relays to suppress the shortened life due to the thermal load.

While the system main relays SMR-B**1** and SMR-B**2** are connected to the positive electrode terminals of the battery packs **10** and **20**, respectively, and the system main relays

SMR-P and SMR-G are connected to the negative electrode terminals of the battery packs **10** and **20** in the battery system of the present embodiment, the present invention is not limited thereto. For example, the system main relays SMR-B**1** and SMR-B**2** may be connected to the negative electrode terminals of the battery packs **10** and **20**, respectively, and the system main relays SMR-P and SMR-G may be connected to the positive electrode terminals of the battery packs **10** and **20**.

While the system main relays SMR-B**1** and SMR-B**2** are alternately set as the system main relay switched last from OFF to ON in the present embodiment, the present invention is not limited thereto. Specifically, it is only required that the number of times the system main relay SMR-B**1** is switched ON last should be equal to the number of times the system main relay SMR-B**2** is switched ON last when a predetermined number of times of switchings of the ignition switch to ON are completed. Thus, the processing of switching ON the system main relay SMR-B**1** or the system main relay SMR-B**2** last may be performed in succession.

For example, the system main relay SMR-B**2** and the system main relay SMR-B**1** can be switched ON in this order in response to the first turn-on and the second turn-on of the ignition switch, respectively. The system main relay SMR-B**1** and the system main relay SMR-B**2** can be switched ON in this order in response to the third turn-on and the fourth turn-on of the ignition switch, respectively. At the fourth switching of the ignition switch to ON, the number of times the system main relay SMR-B**1** is switched ON last is equal to the number of times the system main relay SMR-B**2** is switched ON last.

While the two battery packs **10** and **20** are used in the present embodiment, three or more battery packs may be used. Specifically, three or more battery packs can be connected in parallel. When the three or more battery packs are used, system main relays corresponding to the system main relays SMR-B**1** and SMR-B**2** are connected to the respective battery packs.

When three or more system main relays are used, the system main relay switched last from OFF to ON may also be changed in turn. For example, when three system main relays (referred to as a first relay, a second relay, and a third relay) are used, the relay switched last from OFF to ON may be changed in the order of the first relay, the second relay, then the third relay. It is only required that the number of times the first relay, the second relay, and the third relay are switched ON last should be equal to each other when a predetermined number of switchings of the ignition switch to ON are completed.

## Embodiment 2

A battery system which is Embodiment 2 of the present invention will be described. FIG. **3** is a diagram showing the configuration of part of the battery system which is the present embodiment. Components having the same functions as those of the components described in Embodiment 1 are designated with the same reference numerals, and detailed description thereof is omitted. The description in the present embodiment is mainly focused on differences from Embodiment 1.

In the present embodiment, a controller **41** estimates damage total amounts D**1**_total and D**2**_total of system main relays SMR-B**1** and SMR-B**2**. The system main relays SMR-B**1** and SMR-B**2** suffer damage due to a thermal load when an inrush current flows. Each time the system main relays SMR-B**1** and SMR-B**2** are switched from OFF to ON, the damage is accumulated in the system main relays SMR-B**1** and SMR-B**2**. The accumulated damage corresponds to the damage total amounts D**1**_total and D**2**_total.

When the damage total amounts D**1**_total and D**2**_total reach a threshold value Dth, the controller **41** encourages exchange of the system main relays SMR-B**1** and SMR-B**2**. The threshold value Dth is a preset value in view of the lives of the system main relays SMR-B**1** and SMR-B**2**.

The controller **41** outputs a control signal to an information output section **43** when the damage total amounts D**1**_total and D**2**_total of the system main relays SMR-B**1** and SMR-B**2** reach the threshold value Dth. The information output section **43** receives the control signal from the controller **41** and outputs information encouraging the exchange of the system main relays SMR-B**1** and SMR-B**2**. The information output section **43** is only required to notify a user or the like of the information encouraging the exchange of the system main relays SMR-B**1** and SMR-B**2**. For example, a lamp, a display, and a speaker can be used as the information output section **43**.

When the lamp is used as the information output section **43**, the controller **41** can light the lamp when the damage total amounts D**1**_total and D**2**_total reach the threshold value Dth.

When the display is used as the information output section **43**, the controller **41** can display information encouraging the exchange of the system main relays SMR-B**1** and SMR-B**2** on the display. The displayed information on the display is only required to be information which allows the user to know that the exchange of the system main relays SMR-B**1** and SMR-B**2** is encouraged. Characters or symbols can be used as appropriate for the displayed information.

When the speaker is used as the information output section **43**, the controller **41** can output information encouraging the exchange of the system main relays SMR-B**1** and SMR-B**2** as a sound from the speaker. The details of the sound can be set as appropriate.

FIG. **4** is a flow chart showing operation of the battery system in the present embodiment. Processing shown in FIG. **4** is performed by the controller **41**. The processing shown in FIG. **4** can be performed, for example after the processing shown in FIG. **2** is completed.

At step S**201**, the controller **41** determines whether the system main relay SMR-B**1** or SMR-B**2** is switched ON last. When the system main relay switched ON last is the system main relay SMR-B**1**, the process proceeds to step S**202**; When the system main relay switched ON last is the system main relay SMR-B**2**, the process proceeds to step S**206**.

At step S**202**, the controller **41** calculates a damage amount D**1** of the system main relay SMR-B**1**. The damage amount D**1** refers to the amount of damage to the system main relay SMR-B when the system main relay SMR-B**1** is switched ON.

The damage amount D**1** can be calculated (estimated) with one of three methods described below. The calculation method of the damage amount D**1** is not limited to the methods described below. In other words, any method can be employed as long as the amount of damage due to the thermal load can be specified.

In the first method, a terminal voltage V of the system main relay SMR-B**1** and the value of an electric current I passing through the system main relay SMR-B**1** are measured first. The voltage V corresponds to a difference between the total voltage of a first battery pack **10** and the total voltage of a second battery pack **20** before the system main relay SMR-B**1** is switched ON. The damage amount D**1** can be calculated on the basis of the following expression (2).

[Expression 1]

$$D1=\int I(t)V(t)dt \quad (2)$$

In the expression (2), t represents time. I(t) represents a change in the current value I over time. V(t) represents a change in the voltage V over time.

In the second method, the terminal voltage V of the system main relay SMR-B**1** is measured. The voltage V corresponds to the difference between the total voltage of the first battery pack **10** and the total voltage of the second battery pack **20** before the system main relay SMR-B**1** is switched ON. The relationship between the voltage V and the damage amount D**1** is previously specified and stored as a map in the memory **41***a*. The damage amount D**1** can be specified by using the map and the measured voltage V.

When the damage amount D**1** changes with temperature, the parameter of the temperature can be included in the map. Specifically, it is possible to previously create a map with which the damage amount D**1** can be determined by specifying the temperature and the voltage V.

In the third method, a peak current Ipeak passing the system main relay SMR-B**1** is measured when chattering is produced in the system main relay SMR-B**1**. The damage amount D**1** can be calculated on the basis of the following expression (3).

[Expression 2]

$$D1=I_{peak}\times\int I(t)V(t)dt \quad (3)$$

In the expression (3), t represents time. I(t) represents a change in the current value I over time. V(t) represents a change in the voltage V over time.

At step S**203**, the controller **41** calculates the damage total amount D**1**_total of the system main relay SMR-B**1**. Specifically, the controller **41** calculates the damage total amount D**1**_total in the current processing by adding the damage amount D**1** calculated at step S**202** to a damage total amount D**1**_total calculated up to the previous processing.

At step S**204**, the controller **41** determines whether or not the damage total amount D**1**_total calculated at step S**203** is larger than the threshold value Dth. When the damage total amount D**1**_total is larger than the threshold value Dth, the process proceeds to step S**205**, and when not, the processing is ended.

At step S**205**, the controller **41** determines that the life of the system main relay SMR-B**1** has expired, and drives the information output section **43**. The user can know that the life of the system main relay SMR-B**1** has expired based on the output from the information output section **43**.

On the other hand, the controller **41** calculates a damage amount D**2** of the system main relay SMR-B**2** at step S**206**. The calculation method of the damage amount D**2** is the same as the calculation method of the damage amount D**1**.

At step S**207**, the controller **41** calculates the damage total amount D**2**_total of the system main relay SMR-B**2**. Specifically, the controller **41** calculates the damage total amount D**2**_total in the current processing by adding the damage amount D**2** calculated at step S**206** to a damage total amount D**2**_total calculated up to the previous processing.

At step S**208**, the controller **41** determines whether or not the damage total amount D**2**_total calculated at step S**207** is larger than the threshold value Dth. When the damage total amount D**2**_total is larger than the threshold value Dth, the process proceeds to step S**209**, and when not, the processing is ended.

At step S**209**, the controller **41** determines that the life of the system main relay SMR-B**2** has expired, and drives the information output section **43**. The user can know that the life of the system main relay SMR-B**2** has expired based on the output from the information output section **43**.

According to the present embodiment, the lives of the system main relays SMR-B**1** and SMR-B**2** can be determined by calculating the damage total amounts D**1**_total and D**2**_total of the system main relays SMR-B**1** and SMR-B**2**, respectively. The system main relays SMR-B**1** and SMR-B**2** can be exchanged on the basis of the lives of the system main relays SMR-B**1** and SMR-B**2**.

## Embodiment 3

A battery system which is Embodiment 3 of the present invention will be described. Components having the same functions as those of the components described in Embodiment 1 are designated with the same reference numerals, and detailed description thereof is omitted. The description in the present embodiment is mainly focused on differences from Embodiments 1 and 2.

In the present embodiment, damage total amounts D**1**_total and D**2**_total of system main relays SMR-B**1** and SMR-B**2** are calculated similarly to Embodiment 2. The system main relay having the smaller one of the damage total amount D**1**_total and D**2**_total is switched ON last. FIG. **5** is a flow chart for describing processing of the battery system in the present embodiment. The processing shown in FIG. **5** is performed by a controller **41**.

At step S**301**, the controller **41** calculates the damage total amounts D**1**_total and D**2**_total of the system main relays SMR-B**1** and SMR-B**2**, respectively. The damage total amounts D**1**_total and D**2**_total can be calculated with the method described in Embodiment 2.

Specifically, each time the system main relay SMR-B**1** or the system main relay SMR-B**2** is switched ON last, damage amounts D**1** and D**2** of the system main relays SMR-B**1** and SMR-B**2** are calculated. The damage amounts D**1** and D**2** can be added up to obtain the damage total amounts D**1**_total and D**2**_total.

At step S**302**, the controller **41** determines whether or not the damage total amount D**1**_total is larger than the damage total amount D**2**_total. When the damage total amount D**1**_total is larger than the damage total amount D**2**_total, the controller **41** determines that the system main relay SMR-B**1** is deteriorated more than the system main relay SMR-B**2**, and proceeds to processing at step S**303**.

On the other hand, when the damage total amount D**2**_total is larger than the damage total amount D**1**_total, the controller **41** determines that the system main relay SMR-B**2** is deteriorated more than the system main relay SMR-B**1**, and proceeds to processing at step S**304**.

At step S**303**, the controller **41** sets the system main relay SMR-B**2** as the system main relay switched ON last. This setting information is stored in a memory **41***a*. When an ignition switch is switched from OFF to ON next, the controller **41** switches the system main relay SMR-B**1** ON and then switches the system main relay SMR-B**2** ON based on the setting information stored in the memory **41***a*. Thus, of the system main relays SMR-B**1** and SMR-B**2**, the system main relay SMR-B**2** is the one that is switched ON last.

At step S**304**, the controller **41** sets the system main relay SMR-B**1** as the system main relay switched ON last. This setting information is stored in the memory **41***a*. When the ignition switch is switched from OFF to ON next, the controller **41** switches the system main relay SMR-B**2** ON and then switches the system main relay SMR-B**1** ON based on the setting information stored in the memory **41***a*. Thus, of the system main relays SMR-B**1** and SMR-B**2**, the system main relay SMR-B**1** is the one that is switched ON last.

According to the present embodiment, the system main relay switched ON last is changed depending on the deterioration states of the system main relays SMR-B**1** and SMR-B**2**. This can suppress variations in deterioration between the system main relays SMR-B**1** and SMR-B**2**. In other words, the damage can be shared between the system main relays SMR-B**1** and SMR-B**2** to increase the lives of the system main relays SMR-B**1** and SMR-B**2**.

The invention claimed is:

**1**. A battery system comprising:

a first battery and a second battery, each of the batteries performing charge and discharge;

a first relay that is connected in series with the first battery and switched between an ON state in which the charge and discharge of the first battery are allowed and an OFF state in which the charge and discharge of the first battery are prohibited;

a second relay that is connected in series with the second battery and switched between an ON state in which the charge and discharge of the second battery are allowed and an OFF state in which the charge and discharge of the second battery are prohibited; and

a controller controlling the ON state and the OFF state of each of the first relay and the second relay,

wherein a group of the first battery and the first relay and a group of the second battery and the second relay are connected in parallel with respect to a motor generator that receives an electric energy from each of the first and second batteries to generate a kinetic energy for running of a vehicle, and

the controller selects a first case and a second case when the first and second relays are switched to the ON state to connect the first and second batteries to the motor generator, the first case where the second relay is switched to the ON state after switching the first relay to the ON state, the second case where the first relay is switched to the ON state after switching the second relay to the ON state.

**2**. The battery system according to claim **1**, wherein the controller alternately selects the first and second cases each time the first and second relays are switched to the ON state to connect the first and second batteries to the motor generator.

**3**. The battery system according to claim **2**, further comprising an information output section outputting information about the life of each of the first relay and the second relay,

wherein the controller estimates damages of the first and second relays due to a thermal load when each of the first relay and the second relay is switched from the OFF state to the ON state, based on a terminal voltage of each of the first relay in the OFF state and the second relay in the OFF state, and

drives the information output section when the estimated damage reaches a threshold value.

**4**. The battery system according to claim **1**, wherein the controller estimates damages of the first and second relays due to a thermal load when each of the first relay and the second relay is switched from the OFF state to the ON state, based on a terminal voltage of each of the first relay in the OFF state and the second relay in the OFF state, and

switches one of the first relay and the second relay that has smaller estimated damage to the ON state last when the first and second relays are switched to the ON state to connect the first and second batteries to the motor generator.

**5**. The battery system according to claim **4**, further comprising an information output section outputting information about the life of each of the first relay and the second relay,

wherein the controller estimates damages of the first and second relays due to a thermal load when each of the first relay and the second relay is switched from the OFF state to the ON state, based on a terminal voltage of each of the first relay in the OFF state and the second relay in the OFF state, and

drives the information output section when the estimated damage reaches a threshold value.

**6**. The battery system according to claim **4**, wherein the controller calculates the damage of each of the first and second relays based on the following expression,

$$D=\int I(t)V(t)dt$$

where D represents the damage of each of the first and second relays, I represents an electric current passing through each of the first and second relays, V represents the terminal voltage of each of the first and second relays and t represents time.

**7**. The battery system according to claim **4**, wherein the controller calculates the damage of each of the first and second relays based on the following expression,

$$D=I_{peak}\times\int I(t)V(t)dt$$

where D represents the damage of each of the first and second relays, Ipeak represents a peak current passing through each of the first and second relays, I represents an electric current passing through each of the first and second relays, V represents the terminal voltage of each of the first and second relays and t represents time.

**8**. The battery system according to claim **4**, wherein the controller calculates the damage of each of the first and second relays based on a correspondence between the damage and a difference between total voltages of the first and second batteries.

**9**. The battery system according to claim **1**, further comprising an information output section outputting information about the life of each of the first relay and the second relay,

wherein the controller estimates damages of the first and second relays due to a thermal load when each of the first relay and the second relay is switched from the OFF state to the ON state, based on a terminal voltage of each of the first relay in the OFF state and the second relay in the OFF state, and

drives the information output section when the estimated damage reaches a threshold value.

**10**. The battery system according to claim **1**, further comprising a third relay switched between an ON state in which the charge and discharge of the first battery and the second battery are allowed and an OFF state in which the charge and discharge of the first battery and the second battery are prohibited,

wherein the controller controls the ON state and the OFF state of the third relay.

**11**. The battery system according to claim **1**, wherein each of the first battery and the second battery is an assembled battery formed of a plurality of cells connected in series.

**12**. The battery system according to claim **11**, wherein each of the first battery and the second battery outputs an energy for use in running of a vehicle.

**13**. A control method of a battery system comprising a first battery and a second battery, each of the batteries performing charge and discharge, a first relay connected in series with the first battery and switched between an ON state in which the charge and discharge of the first battery are allowed and an OFF state in which the charge and discharge of the first battery are prohibited, and a second relay connected in series with the second battery and switched between an ON state in which the charge and discharge of the second battery are allowed and an OFF state in which the charge and discharge of the second battery are prohibited, a group of the first battery and the first relay and a group of the second battery and the second relay are connected in parallel with respect to a motor generator that receives an electric energy from each of the first and second batteries to generate a kinetic energy for running of a vehicle, the method comprising the step of:

selecting a first case and a second case when the first and second relays are switched to the ON state to connect the first and second batteries to the motor generator, the first case where the second relay is switched to the ON state after switching the first relay to the ON state, the second case where the first relay is switched to the ON state after switching the second relay to the ON state.

**14**. The control method according to claim **13**, wherein the first and second cases are alternately selected each time the first and second relays are switched to the ON state to connect the first and second batteries to the motor generator.

**15**. The control method according to claim **13**, wherein damages of the first and second relays due to a thermal load when each of the first relay and the second relay is switched from the OFF state to the ON state is estimated, based on a terminal voltage of each of the first relay in the OFF state and the second relay in the OFF state, and

one of the first relay and the second relay that has smaller estimated damage is switched to the ON state last when the first and second relays are switched to the ON state to connect the first and second batteries to the motor generator.

**16**. The control method according to claim **13**, wherein damages of the first and second relays due to a thermal load when each of the first relay and the second relay is switched from the OFF state to the ON state is estimated, based on a terminal voltage of each of the first relay in the OFF state and the second relay in the OFF state, and

information about the life of each of the first relay and the second relay is output when the estimated damage reaches a threshold value.

**17**. The control method according to claim **14**, wherein damages of the first and second relays due to a thermal load when each of the first relay and the second relay is switched from the OFF state to the ON state is estimated, based on a terminal voltage of each of the first relay in the OFF state and the second relay in the OFF state, and

information about the life of each of the first relay and the second relay is output when the estimated damage reaches a threshold value.

**18**. The control method according to claim **15**, wherein damages of the first and second relays due to a thermal load when each of the first relay and the second relay is switched from the OFF state to the ON state is estimated, based on a terminal voltage of each of the first relay in the OFF state and the second relay in the OFF state, and

information about the life of each of the first relay and the second relay is output when the estimated damage reaches a threshold value.

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